Autonomous Propellant Loading Project

Advanced Exploration Systems Program | Human Exploration And Operations Mission Directorate (HEOMD)

ABSTRACT

The AES Autonomous Propellant Loading (APL) project consists of three activities. The first is to develop software that will automatically control loading of cryogenic propellant into launch vehicles to ensure safe and successful propellant loading.

The second part of the project is to build a system to demonstrate zero-loss cryogenic propellant (liquid hydrogen) transfer and storage, hydrogen liquifaction, and liquid hydrogen densification.

The third area is developing systems to develop technologies to monitor the status of composite tanks used to store cryogenic propellants to ensure they are safe to use.

This project builds on the AES Integrated Ground Operations Demonstration Unit (IGODU) project.

ANTICIPATED BENEFITS

To NASA funded missions:

This technology should reduce the number of people needed to load cryogenic propellants into launch vehicles as well as increase safety.

To NASA unfunded & planned missions:

This technology should reduce the number of people needed to load cryogenic propellants into launch vehicles as well as increase safety.

To other government agencies:

If used for launch vehicles, this technology should reduce the number of people needed to load cryogenic propellants into launch vehicles as well as increase safety.

To the commercial space industry:

If used for launch vehicles, this technology should reduce the number of people needed to load cryogenic propellants into

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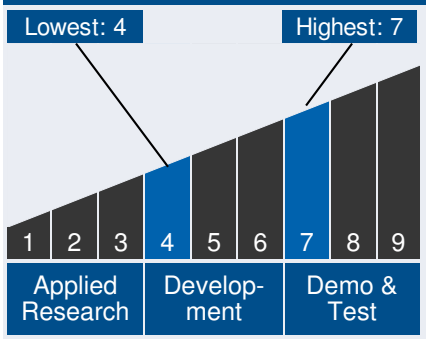
Technology Maturity



Management Team

Program Director:

- Jason Crusan

launch vehicles as well as increase safety.

To the nation:

Improved safety and reduced cost of loading cryogenic propellants into launch vehicles.

DETAILED DESCRIPTION

The APL project consists of three activities: autonomous control software; demonstrating cryogenic zero-loss transfer and storage, liquifaction, and densification; and developing techniques to monitor composite cryogen storage tanks. As well as being used on Earth, these technologies can be used as part of in situ resource utilization (ISRU), for example to liquify, densify, store, and transfer cryogenic propellants produced on Mars to return astronauts to Earth.

Autonomous Control Software:

The autonomous control software contains a physics-based model of the expected system operation. If the inputs from sensors do not agree with the expected system state, the software will determine and initiate the appropriate steps needed to either keep the system operating safely or shut it down safely. This allows the software to perform reasoning based on sensor inputs to determine the causes of anomalies and take appropriate actions. These actions may include reconfiguring the system or safely shutting it down.

Initially, the software will be tested using the Universal Propellant Servicing System (UPSS), a small launch vehicle facility being built at Kennedy Space Center (KSC). Once demonstrated on UPSS, the technology is anticipated to be infused into the Space Launch System (SLS) vehicle.

Ground Operations Demonstration Unit for Liquid Hydrogen (GODU LH2)

During the Space Shuttle program, engineers at KSC discovered that over 50% of the LH2 purchased by NASA was lost from the

Management Team *(cont.)*

Program Executive:
- Richard Mcginnis

Project Manager:
- John Gurecki

Technology Areas

- Structural Health Monitoring and Thermal Health Monitoring (SHM/THM) System Integration (TA 12.2.3.3)
- Ground and Launch Systems (TA 13)
- Operational Life-Cycle (TA 13.1)
- On-Site Production, Storage, Distribution, and Conservation of Fluids (TA 13.1.1)
- Low-Loss Storage of Cryogens Through Active Means (TA 13.1.1.3)
- Higher-Efficiency Transfer of Cryogens Using Active Means (TA 13.1.1.5)
- Autonomous Command and Control for Integrated Vehicle and Ground Systems (TA 13.1.3)

time it was loaded onto a tanker, offloaded into a storage container at KSC, transferred from the storage container to the Space Shuttle External Tank and the Space Shuttle launched. This part of APL is to eliminate the losses and enhance liquid hydrogen production and storage by:

- Demonstrate zero-loss transfer of LH2 during tanker offload, which has the potential to reduce future SLS LH2 procurement costs by at least 25%
- Demonstrate in-situ liquefaction of LH2
- Demonstrate densification of LH2, which has the potential to improve overall launch vehicle ascent performance by 10% or more.

Tank Health Monitoring (THM)

NASA's future goal of exploring the solar system by traveling beyond low Earth orbit with human missions requires new technologies to reduce weight. One technology being investigated for both structural members and propellant tanks is carbon composites. To ensure safety, the failure modes of tanks must be understood. Health monitoring technology is being developed for both structural members and propellant tanks to understand the mechanics and provide a detection system to prevent unexpected catastrophic failure.

The overall goal of the project is to test composite tanks under cryogenic temperatures to failure in order to develop health monitoring technology that will detect system degradation and mitigate catastrophic failures through improved system health insight.

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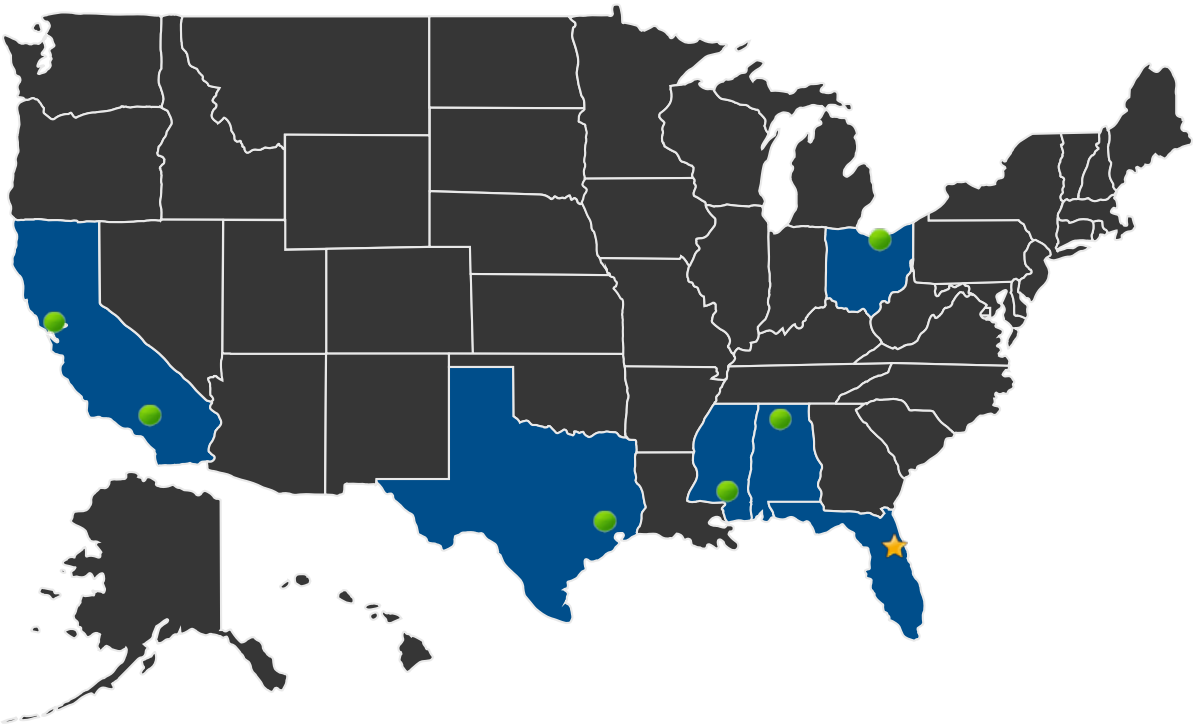
U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

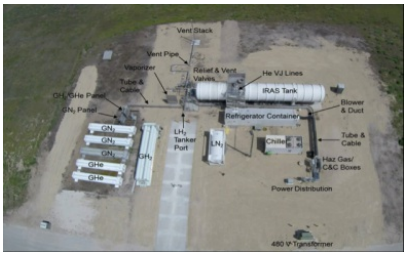
Lead Center:
Kennedy Space Center

Supporting Centers:

- Ames Research Center
- Armstrong Flight Research Center
- Glenn Research Center
- Johnson Space Center
- Marshall Space Flight Center
- Stennis Space Center

IMAGE GALLERY

500 gallon composite tank ready to test to failure



LH2 Test Site

DETAILS FOR TECHNOLOGY 1

Technology Title

Autonomous Propellant Loading

Technology Description

This technology is categorized as software memory for ground support or mission operations

The APL project is developing software that automates cryogenic propellant handling and loading using physics-based models to support reasoning.

Capabilities Provided

Flexible physics-based autonomous control software for cryogenic propellant handling and loading.

Potential Applications

Any launch vehicle that uses cryogenic propellants, both on Earth and at other places in the solar system (e.g., Mars).

Technology Areas

Primary Technology Area:
Materials, Structures, Mechanical Systems and Manufacturing (TA 12)
- Structures (TA 12.2)
  - Reliability and Sustainment (TA 12.2.3)
    - Structural Health Monitoring and Thermal Health Monitoring (SHM/THM) System Integration (TA 12.2.3.3)

Ground and Launch Systems (TA 13)
- Operational Life-Cycle (TA 13.1)
  - Autonomous Command and Control for Integrated Vehicle and Ground Systems (TA 13.1.3)

Continued on following page.

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Performance Metrics

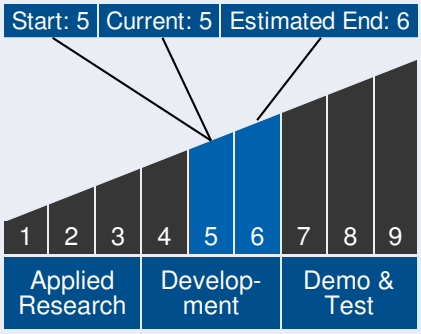
Metric	Unit	Quantity
Reduce number of people needed to load cryogenic propellants	per cent	50

Technology Areas *(cont.)*

Secondary Technology Area:
Ground and Launch Systems (TA 13)
- Operational Life-Cycle (TA 13.1)
  - On-Site Production, Storage, Distribution, and Conservation of Fluids (TA 13.1.1)
    - Low-Loss Storage of Cryogens Through Active Means (TA 13.1.1.3)

Additional Technology Areas:
Ground and Launch Systems (TA 13)
- Operational Life-Cycle (TA 13.1)
  - On-Site Production, Storage, Distribution, and Conservation of Fluids (TA 13.1.1)
    - Higher-Efficiency Transfer of Cryogens Using Active Means (TA 13.1.1.5)

Technology Maturity



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DETAILS FOR TECHNOLOGY 2

Technology Title

Liquid hydrogen liquifaction, densification, and zero loss transfer and storage

Technology Description

This technology is categorized as a hardware system for ground support or mission operations

The APL project is developing a system to demonstrate liquifaction, densification, and zero-loss transfer and storage of cryogenic fluids. The system demonstrated will use hydrogen.

Capabilities Provided

The ability to liquify, densify, plus zero-loss transfer and storage of the cryogenic fluid.

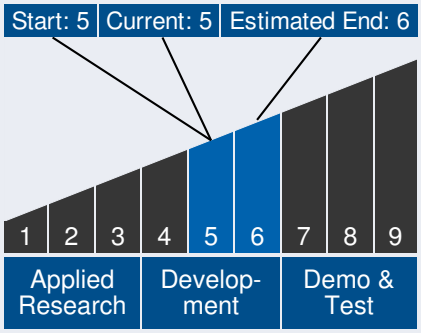
Potential Applications

Launch vehicle propellant prodution, storage, and handling.

Technology Areas

Secondary Technology Area:
Ground and Launch Systems (TA 13)
- Operational Life-Cycle (TA 13.1)
  - On-Site Production, Storage, Distribution, and Conservation of Fluids (TA 13.1.1)

Technology Maturity



DETAILS FOR TECHNOLOGY 3

Technology Title

Tank Health Monitoring

Technology Description

This technology is categorized as a hardware system for manned spaceflight

The APL project is developing health monitoring technology that will detect composite tank degradation, plus the knowledge of how composite tanks degrade when used at crogenic temperatures.

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Capabilities Provided

The ability to monitor composte tank health and predict pending failures.

Potential Applications

Any tank, particularly composite tanks used at cryogenic temperatures.

Technology Areas

Primary Technology Area:
Materials, Structures, Mechanical Systems and Manufacturing (TA 12)

- Structures (TA 12.2)
  - Reliability and Sustainment (TA 12.2.3)
    - Structural Health Monitoring and Thermal Health Monitoring (SHM/THM) System Integration (TA 12.2.3.3)

Technology Maturity